Changkat Changi Secondary School

UNIT 2

Kinematics

Name: ___________________________

Class: ___________

Date: _____________

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"Scientists tell us that the fastest animal on earth, with a top speed of 120 feet per second, is a cow that has been dropped out of a helicopter."

Dave Barry,
American Humorist

NOTES 2.1

LESSON OBJECTIVES
At the end of the lesson, you will be able to:
- state what speed is
- calculate average speed
- state what is velocity
- State what is uniform acceleration and calculate acceleration using $\frac{\text{change in velocity}}{\text{Time taken}}$

Previously, we have learnt how measurement of length, time, mass and density can help scientists and everyone to better understand the nature of objects. In this unit, we will study the movement of objects and use certain terms to describe their motion.

Do you know?
The term "kinematics" is derived from the Greek word κινεῖν, *kinein*, which also means to move and involves the calculation of movement to help us better understand the behaviour of objects.

What is speed?
Speed of a moving object refers to the distance it moved per unit time taken.
This leads to the simple equation for speed:

$$\text{Speed} = \frac{\text{Distance moved}}{\text{time taken}}$$

In symbols, it can be written as :

$$V = \frac{d}{t}$$

Where v = speed (in m/s or ms^{-1})
d = distance moved (in m)
t = time taken (in s)

Note: m/s can also be written as ms^{-1}
Since index laws states that
that 1/s is s^{-1}

Average speed
To calculate average speed, we use the following equation:

$$\text{Average Speed} = \frac{\text{Total distance moved}}{\text{Total time taken}}$$

Watch this video of Usain Bolt versus Wallace Spearmon in a 200 m race@ http://www.youtube.com/watch?v=-dm-ds5rRaM&feature=channel

Qn: What is the average speed of Usain Bolt? Why do we use average speed instead of the term speed?

EXAMPLE

i) A train travels a distance of 40 m in 2.5s. What is its speed? What is the assumption made here?

ii) A car A travels 54 km in 1 hour. Another car B travels 10 m in 1 second. Which car is faster?

iii) Convert 36km/h to m/s

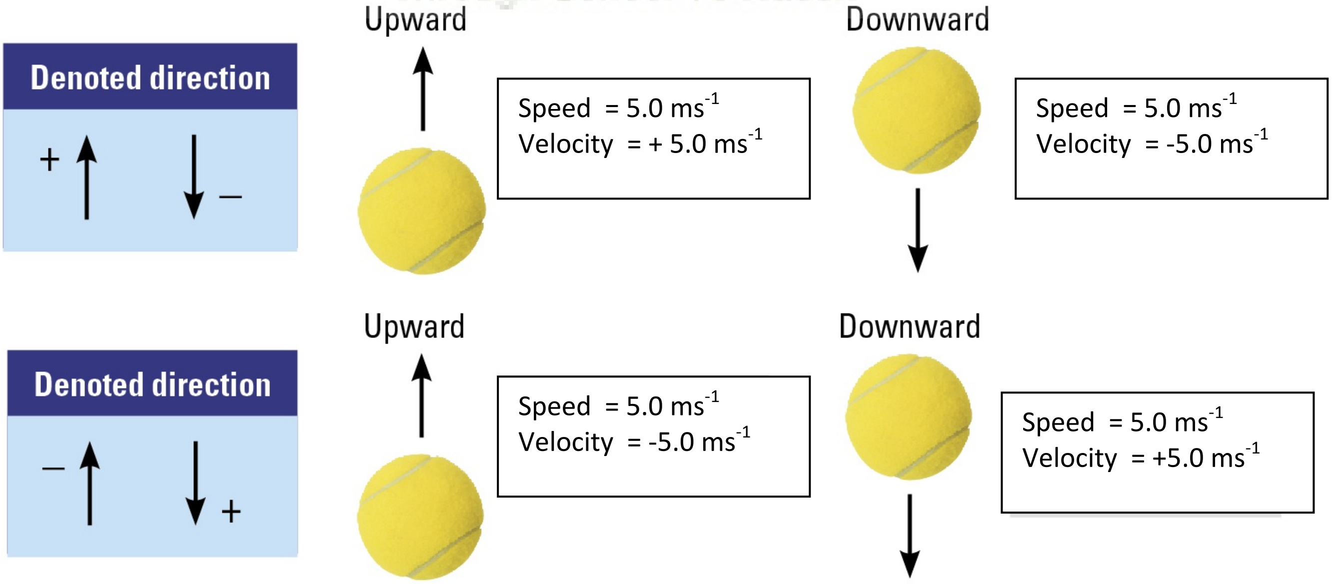
Describe speed in a specified direction

In order to fully describe the motion of an object, it is important to describe both the __________ and ____________________ of an object. To do so, the term ________________ is used.

1. Velocity is defined ____.

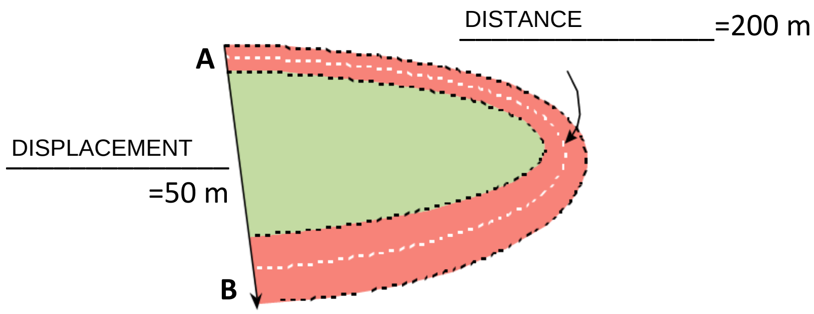
Specifying direction in motion

In describing direction of motion, we usually specify one direction as positive and the opposite direction as negative. The diagrams below show two ways to write velocity of an object.



Since velocity is used to describe the speed of an object in a specific direction, similarly, distance in a specified direction is known as displacement.

Qn In a 200 m race, a girl travels from point A to B. Use the correct term "displacement" or "distance" to fill in the blanks below.



Likewise, velocity can be defined rate of change of displacement.

Acceleration

Earlier on, we watched sprinters run along the track. At certain times, we would see some of them begin to increase or decrease their velocity. This change in velocity is over a period of time is **acceleration.**

Types of acceleration

Acceleration

- **Positive acceleration** --when ~~speed~~ is increasing
- **Negative acceleration** (deceleration) -- when speed is decreasing

Calculating acceleration

Since acceleration is the change in velocity during the time taken, we can write a formula for acceleration:

$$a = \frac{v-u}{t}$$

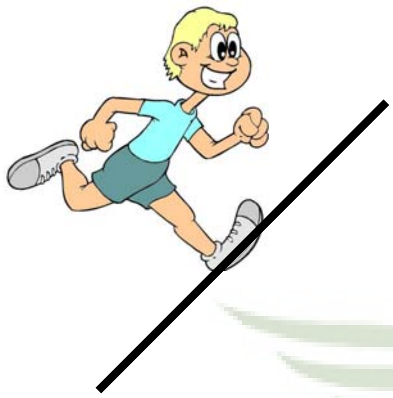
Where a = acceleration (in m/s^2 or ms^{-2})
v = final velocity (in m/s or ms $^{-1}$)
u = initial velocity (in m/s or ms^{-1})
t = time taken (in s)

S.I. unit of acceleration is __________ or __________

EXAMPLES

1. A car starts from rest and travels in a straight path. It reaches a speed of 12 ms^{-1} in 4 s. What is its acceleration, assuming that it accelerates uniformly?

2. A runner was running at a velocity of 8 ms^{-1} and slows down uniformly to a stop in 4 s. Calculate his deceleration.



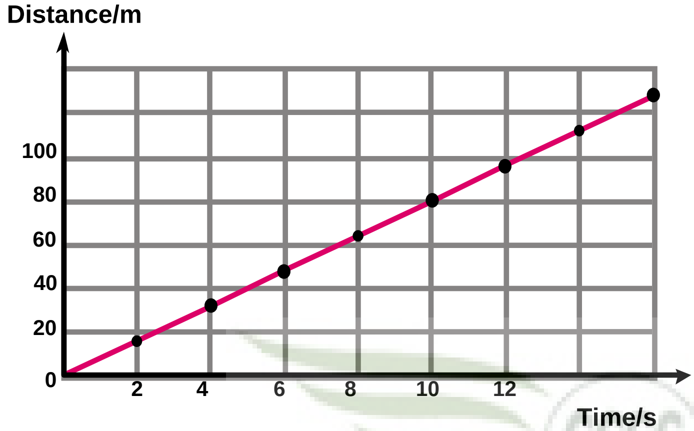
3. A motorcycle was a moving at a constant speed of 15 m/s and accelerated uniformly to 25 m/s in 4 s. Calculate his acceleration.

NOTES 2.2

LESSON OBJECTIVES
At the end of the lesson, you will be able to:
- plot and interpret distance-time and speed-time graphs
- determine the distance travelled by calculating the area under the speed-time graph

Graphs are very useful in showing how an object move and helps us to describe the motion of an object at a certain time. In this unit, we learn how to plot and interpret speed time graphs.

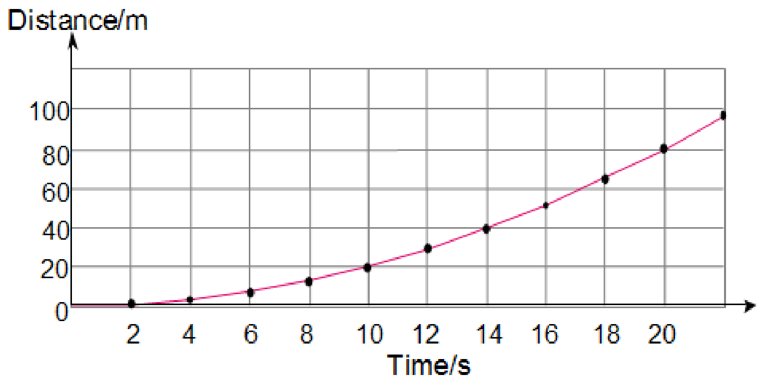
To understand motion of moving objects better, distance moved by objects over time are usually collected as a set of data and plotted onto graph like one shown below.



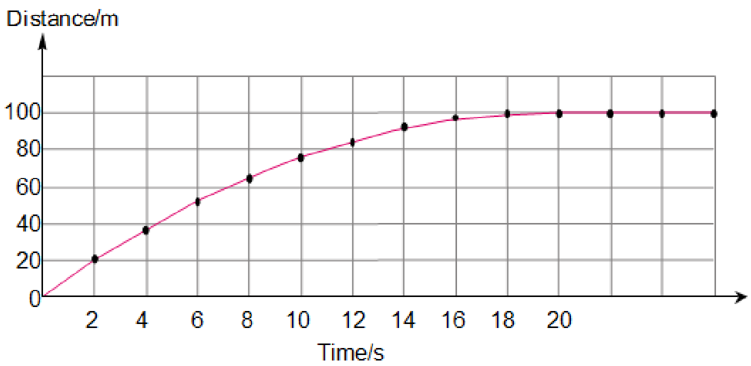
Qn: What is the distance traveled by the object at the end of ten seconds? Is the object moving at a constant rate?

80 m
Yes

Non Uniform distance time graphs
Not all distance time graphs will be a straight line. Sometimes, it would appear as curves as shown below.

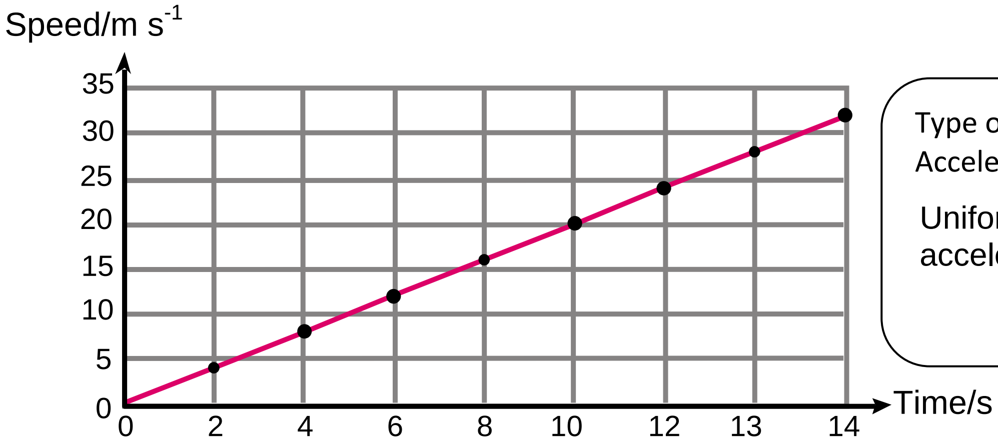


i. Distance time graph for increasing speed



ii. Distance time graph for decreasing speed

Speed time graph with uniform acceleration



Type of line: straight line

Acceleration :

Uniform or constant acceleration

Speed time graphs with non-uniform acceleration

Type of line: Curve

Acceleration :

Increasing acceleration (non- uniform)

Type of line: Curve

Acceleration :

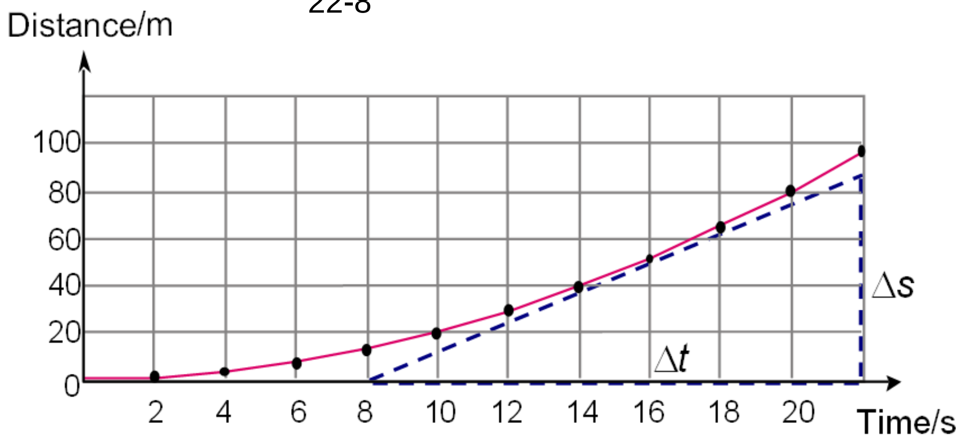
Decreasing acceleration (non-uniform)

Using distance time graphs and speed time graphs

- *Finding instantaneous speed on distance-time graphs*

The instantaneous speed of an object is the speed at a particular instant. It can be found from the gradient of the tangent at a point on the distance-time graph.

Eg. Speed at 16s = $\frac{\Delta s}{\Delta t}$ = $\frac{90}{22-8}$ =



- *Finding uniform acceleration from speed time graph*

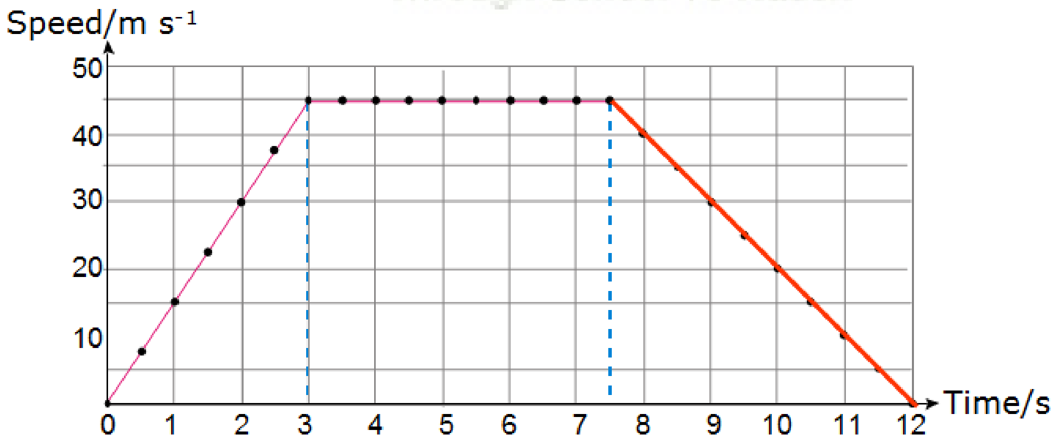
Uniform acceleration of an object can be found from the **gradient** of the graph.

- *Finding distance travelled from speed time graph*

To find distance travelled by an object in a speed time graph, the **area under a speed-time graph** is used.

EXAMPLE

The speed time graph below shows how a car moves from 0 to 12 s.



a) Calculate the acceleration for the first 3 seconds and last 3 secs.

b) Calculate the total distance travelled by the car.

NOTES 2.3

LESSON OBJECTIVES

At the end of the lesson, you will be able to:

- state that the acceleration of free fall near to Earth is approximately 10 m s^{-2}
- describe motion of bodies in free fall with and without air resistance
- understand what terminal velocity is

Galileo's leaning tower of Pisa experiment

In 1634, a famous Italian scientist Galileo Galilei dropped two objects of different masses from the leaning tower of Pisa and discovered that both fell at the same rate and reach the ground at about the same time.

In other words, the acceleration of a free falling object is at a constant rate, regardless of the material, size or shape

Acceleration of free fall

The acceleration of an object dropped without any additional force is known as **acceleration of free fall**. The symbol g______was given to it and it has been experimentally determined to be 9.8 ms^{-2}. For our calculations, we will round this number to 10 m/s2________.

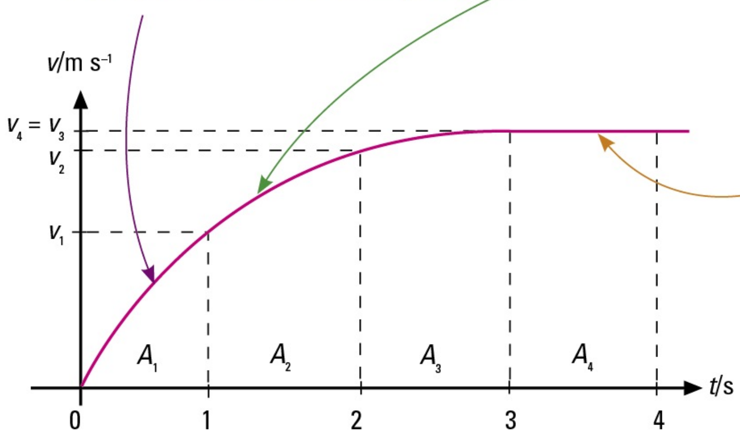
Try it!

Drop a textbook and a piece of paper at the same time. Now, place the piece of paper on top of the textbook. What happens now? Can you explain the difference?

Speed time graph of a free falling piece of paper

1. From $t = 0$ s to $t = 1$ s, the velocity of the paper increases from zero to v_1 rapidly (i.e. acceleration is great).

2. From $t = 1$ s to $t = 3$ s, the velocity of the paper continues to increase from v_1 to v_3 (where $v_3 > v_2 > v_1$). However, the rate of increase of velocity from v_1 to v_2 or from v_2 to v_3 is less than that from zero to v_1 over the same time interval of 1 s (i.e. acceleration is smaller).



3. From $t = 3$ s to $t = 4$ s and beyond, the velocity of the paper does not increase any more but remains at a constant (i.e. $v_4 = v_3$ = maximum constant velocity reached). This maximum constant velocity is called the **terminal velocity**. When terminal velocity happens, the acceleration is zero.

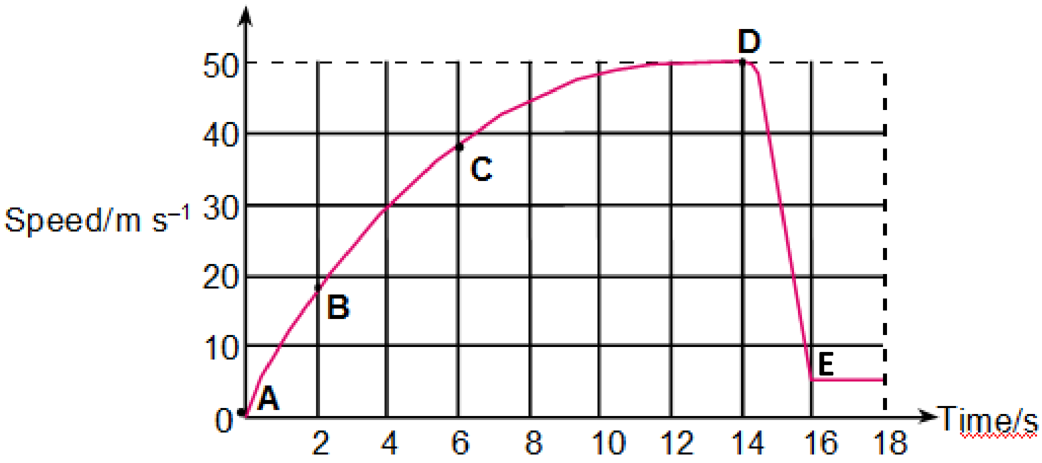
Terminal velocity

When a free falling object moves at its maximum constant velocity, there are equal forces_____ acting on him upwards and downwards and it will no longer accelerate.

This is known as terminal velocity. acceleration is zero

Speed time graph of a parachutist

A parachutist jumps from an aircraft and falls through the air. After some time he opens his parachute. Below is the speed time graph of the parachutist.



Motion of the parachutist at points:

A At rest

B His speed is increasing at decreasing rate.

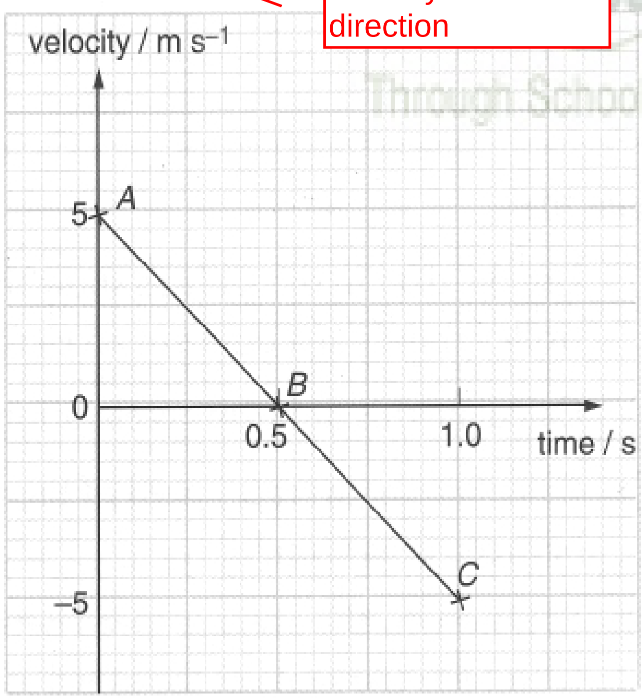
C His speed is increasing at decreasing rate

D Parachute opened

E He reaches second terminal velocity (5 m/s)

Speed time graph of an object thrown upwards and falling down

Velocity has direction



Motion of object at points :

A to B: Object is going upwards

B to C: Object is falling downwards

Acceleration of object :